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Patent claims

1. Semiconductor sensor element having

a substrate base (1),

a homogeneous semiconductor layer (2, 2f) which is disposed on the substrate base (1) and contains semiconductor compounds based on nitrides of the main Group III elements or is formed therefrom,

the surface of the homogeneous semiconductor layer (2, 2f) orientated towards the substrate base (1) at least partially not abutting directly on the substrate base (1) or having a spacing from the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f),

characterised in that

at least two electrical conducting contacts (5) for conducting an electrical output signal which can be generated by the homogeneous semiconductor layer (2, 2f) on the basis of a change in a physical variable to be determined by means of the semiconductor sensor element are disposed on, at and/or under the homogeneous semiconductor layer (2, 2f) or are integrated in the latter.

2. Semiconductor sensor element according to the preceding claim,

characterised in that

at least one of the contacts (5) is disposed in the region of the region (2a) (spaced region) of the homogeneous semiconductor layer (2, 2f), which region does not abut directly on the substrate base (1) or has a spacing from the surface of the substrate base (1) and in that at least one of the contacts (5) is disposed in the region of a region (2b) (non-spaced region) of the homogeneous semiconductor layer (2, 2f), which region does abut directly on the substrate base (1) or has no spacing from the surface of the substrate base (1).

3. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the homogenoeus semiconductor layer (2, 2f) has a raised region or mesa region (9) which, in the direction perpendicular to the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f), has a greater thickness than a region (non-mesa region) of the homogeneous semiconductor layer (2, 2f), which region abuts on this region (9) in a direction parallel to the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f).

4. Semiconductor sensor element according to the preceding claim,

characterised in that

the raised region or mesa region (9) is disposed such that it extends in a direction parallel to the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f) partially over the spaced region (2a) of the homogeneous semiconductor layer (2, 2f) and such that it extends partially over

the non-spaced region (2b) of the homogeneous semiconductor layer (2, 2f).

5. Semiconductor sensor element according to the preceding claim,

characterised in that

the transition from the spaced region (2a) to the non-spaced region (2b) is effected in the direction parallel to the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f) in the region of the centre of the raised region or mesa region (9).

6. Semiconductor sensor element according to one of the claims 3 to 5,

characterised in that

at least one of the contacts (5) is disposed directly on and/or in the region of an outer edge of the raised region or mesa region (9).

7. Semiconductor sensor element according to one of the claims 3 to 6,

characterised in that

the homogeneous semiconductor layer (2, 2f) in the non-mesa region in the direction perpendicular to the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f) has a thickness of above 0.2 μm and/or below 50 μm, in particular of above 0.5 μm and/or below 5 μm, and/or in that the homogeneous semiconductor layer (2, 2f) in the raised region or mesa region (9) has the thickness of the non-mesa region and in addition a thickness of above 20 nm and/or below 1000 nm, in particular of above 50 nm and/or below 300 nm.

8. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the substrate base (1) contains silicon Si or is formed therefrom.

9. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the homogeneous semiconductor layer (2, 2f) contains semiconductor structures based on a main group III-nitride in the form of $Al_xGa_{1-x}N$ or $In_xGa_{1-x}N$ or $In_xAl_{1-x}N$ with a relative element content of $0 <= x <= 1.0$ or is formed therefrom.

10. Semiconductor sensor element according to the preceding claim,

characterised in that

the homogeneous semiconductor layer (2, 2f) contains GaN or is formed therefrom.

11. Semiconductor sensor element according to one of the preceding claims,

characterised in that

a spatial region present due to the spacing between the homogeneous semiconductor layer (2, 2f) and the substrate base (1) or between their surfaces orientated towards each other is not filled

so that the semiconductor layer (2, 2f) relative to the substrate base is at least partially cantilevered.

12. Semiconductor sensor element according to one of the claims 1 to 10,

characterised in that

a spatial region present due to the spacing between the homogeneous semiconductor layer (2, 2f) and the substrate base (1) or between their surfaces orientated towards each other is filled at least partially with a non-metallic and non-semiconducting material.

13. Semiconductor sensor element according to the preceding claim,

characterised in that,

by means of the material, the heat transfer properties and/or the mechanical properties and/or the high frequency properties of the sensor element can be improved.

14. Semiconductor sensor element according to one of the claims 12 to 13,

characterised in that

the material contains SiO_2 and/or Si_xN_y (in particular SiN) and/or diamond and/or DLC (diamond-like carbon) and/or silicone-like filling materials and/or Al_2O_3 and/or thermally conductive plastic materials or is formed therefrom.

15. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the homogeneous semiconductor layer (2, 2f) is undoped or p-doped or n-doped.

16. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the extension of the homogeneous semiconductor layer (2, 2f) in a direction essentially perpendicular to its surface orientated towards the substrate base (1) is above 0.2 μm and/or below 50 μm, in particular above 0.5 μm and/or below 5 μm.

17. Semiconductor sensor element according to one of the preceding claims,

characterised in that

there is disposed on or at the homogeneous semiconductor layer (2, 2f) on the side thereof orientated away from the substrate base, a cover layer (2e) of $Al_yGa_{1-y}N$ or $In_yGa_{1-y}N$ or $In_yAl_{1-y}N$ with a relative element content of $0 <= y <= 1.0$, in order to form a heterostructure of semiconductor compounds based on nitrides of the main Group III elements.

18. Semiconductor sensor element according to the preceding claim and according to one of the claims 3 to 7,

characterised in that

the cover layer (2e) is disposed only on or at the raised region or mesa region (9) but not in the non-mesa region.

19. Semiconductor sensor element according to one of the claims 17 or 18,

characterised in that

the cover layer (2e) is formed from AlGaN, in particular with 0.1 <= y <= 0.3, particularly preferred with 0.15 <= y <= 0.25.

20. Semiconductor sensor element according to one of the claims 17 to 19,

characterised in that

the cover layer (2e) is mechanically distorted and/or in that the extension of the cover layer (2e) in a direction essentially perpendicular to its surface orientated towards the substrate base (1) is in the range of above 5 nm and/or below 1000 nm, in particular in the range of above 10 nm and/or below 200 nm.

21. Semiconductor sensor element according to one of the claims 17 to 20,

characterised in that

the cover layer (2e) is undoped or p-doped or n-doped.

22. Semiconductor sensor element according to one of the claims 17 to 21,

characterised in that

there is disposed on or at the cover layer (2e) on the side thereof orientated away from the substrate base, at least one further homogeneous semiconductor layer with $Al_zGa_{1-z}N$ or $In_zGa_{1-z}N$ or $In_zAl_{1-z}N$ with a relative element content of $0 <= z <= 1.0$.

23. Semiconductor sensor element according to the preceding claim,

characterised in that

the further semiconductor layer is undoped or p-doped or n-doped.

24. Semiconductor sensor element according to claim 15 or 21 or the preceding claim,

characterised in that

the doping material content is greater than 0 atoms per cm^3 and/or smaller than 10^{20} per cm^3 and/or in that the doping material contains silicon Si and/or magnesium Mg or is formed therefrom and/or in that a doped layer has at least one volume doping and/or at least one pulsed doping.

25. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the electrical conducting contacts (5) are p- and/or n-contacts.

26. Semiconductor sensor element according to the preceding claim,

characterised in that

an n-contact contains Al and/or Ti or is formed therefrom, the thickness of the contact being up to 1000 nm, particularly preferred up to 200 nm.

27. Semiconductor sensor element according to claim 25 or 26,

characterised in that

a p-contact has a layer sequence in the subsequently mentioned sequence: an Au layer, an Ni layer and an Au layer, the thickness of each of the layers being preferably up to 1000 nm, particularly preferred up to 200 nm.

28. Semiconductor sensor element according to one of the claims 17 to 27,

characterised in that

the electrical conducting contacts (5) are disposed such that, with their help, an electrical output signal produced in the transition region between the homogeneous semiconductor layer (2, 2f) and the cover layer (2e) can be conducted and/or in that the electrical conducting contacts (5) are disposed directly at the interface between the homogeneous semiconductor layer (2, 2f) and the cover layer (2e).

29. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the electrical conducting contacts (5) have a metallisation.

30. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the physical variable to be determined is the pressure, the temperature, a force, a deflection and/or an acceleration.

31. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the change in the physical variable to be determined by the homogeneous semiconductor layer (2, 2f) via a change in the spatial state, shape, volume, structure of a surface and/or a deflection or bulge relative to the substrate base (1) of the semiconductor layer (2, 2f) can be converted directly into the electrical output signal.

32. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the output signal can be generated by means of piezoelectric properties or mechanical changes in the lattice of the homogeneous semiconductor layer (2, 2f) or represents a change in charge carrier density on a surface of the homogeneous semiconductor layer (2, 2f) or another electrical variable, in particular a current, a voltage or an electrical resistance.

33. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) at at least one anchor point (3) or abuts on the substrate base (1) via at least one interface to the substrate base (1) such that at least one part (2a) of the part of the homogeneous semiconductor layer (2, 2f), which part is not connected at the anchor point or does not abut on the substrate base (1), can be deflected directly relative to the substrate base (1), by means of a change in the physical variable to be determined relative to the substrate base (1).

34. Semiconductor sensor element according to the preceding claim,

characterised in that

at least two anchor points (3) of the homogeneous semiconductor layer (2, 2f) have a connection in the form of a part (2b) of the homogeneous semiconductor layer (2, 2f), which part cannot be deflected relative to the substrate base (1) or has an interface to the substrate base (1).

35. Semiconductor sensor element according to claim 33,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) via exactly one anchor point (3) such that this deflectable part (2a) is an essentially linear

bar, the anchor point (3) being disposed at one of the ends of the bar.

36. Semiconductor sensor element according to one of the claims 33 or 34,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) via two anchor points (3) such that this deflectable part (2a) is an essentially linear bar, the two anchor points (3) being disposed at the two ends of the bar.

37. Semiconductor sensor element according to one of the claims 33 or 34,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) via two anchor points (3) such that this deflectable part (2a) is an essentially U-shaped bar, the two anchor points (3) being disposed at the two ends of the U or of the bar.

38. Semiconductor sensor element according to one of the claims 33 or 34,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) via three anchor points (3) such that this deflectable part (2a) is an essentially Y-shaped bar,

the three anchor points (3) being disposed at the three ends of the Y or of the bar.

39. Semiconductor sensor element according to one of the claims 33 or 34,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) via four anchor points (3) such that this deflectable part (2a) is an essentially X- or H-shaped bar, the four anchor points (3) being disposed at the four ends of the X or H or of the bar.

40. Semiconductor sensor element according to one of the claims 33 or 34,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is connected to the substrate base (1) via a plurality of anchor points (3) such that this deflectable part (2a) is an essentially double comb-shaped bar, the anchor points being disposed at ends of the comb tines or at ends of the bar.

41. Semiconductor sensor element according to one of the claims 35 to 40,

characterised in that

the minimum width of a bar in a given direction which is essentially perpendicular to the deflection direction is above 20 μm and/or below 200 μm and/or in that the arithmetical average of the spacing of anchor points is above 300 μm and/or below 5000 μm.

42. Semiconductor sensor element according to one of the claims 33 to 40,

characterised in that

a deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) is formed as a membrane (2c) such that, by means of a difference in the physical variable, in particular in the pressure, on both sides of the membrane (2c), the latter is able to bulge such that, as a result, in this deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) and/or in a part (2b) of the homogeneous semiconductor layer (2, 2f), which part (2b) is connected to said deflectable part (2a) and cannot be deflected relative to the substrate base (1), the output signal can be generated.

43. Semiconductor sensor element according to the preceding claim,

characterised in that

the membrane (2c) is essentially circular or semicircular.

44. Semiconductor sensor element according to one of the preceding claims,

characterised by

at least two electrically connected homogeneous semiconductor layer elements.

45. Semiconductor sensor element according to claim 43 and 44,

characterised in that

at least two semicircular membrane-semiconductor layer elements (2d) are connected together with a circular membrane-semiconductor layer element (2c) such that a temperature-independent pressure sensor is produced.

46. Semiconductor sensor element according to one of the claims 33 to 43,

characterised in that,

on one deflectable part (2a) of the homogeneous semiconductor layer (2, 2f), a solid body (4), preferably of high density, is disposed or fixed such that the solid body (4) can be deflected directly relative to the substrate base (1) by a change in the physical variable to be determined and, as a result, in this deflectable part (2a) of the homogeneous semiconductor layer (2, 2f) and/or in a part (2b) of the homogeneous semiconductor layer (2, 2f), which part (2b) is connected to said deflectable part (2a) and cannot be deflected relative to the substrate base (1), the output signal can be generated.

47. Semiconductor sensor element according to one of the preceding claims,

characterised in that

the sensor element and/or the homogeneous semiconductor layer (2, 2f) is configured as a functional unit with integrated electrical or electronic circuits which have semiconductor structures based on a main Group III-nitride.

48. Semiconductor sensor element according to the preceding claim,

characterised in that

the circuits have diode structures and/or transistor elements and/or temperature sensor elements and/or in that the circuits are compensation circuits or amplifier circuits, in particular for signal amplification.

49. Semiconductor sensor element according to one of the claims 47 to 48,

characterised in that

the circuits have Schottky contacts and/or in that the circuits are configured as a Wheatstone bridge.

50. Measurement method for determining the change in a physical variable,

a homogeneous semiconductor layer (2, 2f) which contains semiconductor compounds based on main Group III-nitride elements or is formed therefrom being disposed on or at a substrate base (1) such that the surface of the homogeneous semiconductor layer (2, 2f) orientated towards the substrate base (1) at least partially does not abut directly on the substrate base (1) or has a spacing from the surface of the substrate base (1) orientated towards the homogeneous semiconductor layer (2, 2f),

characterised in that,

on the basis of the change in the physical variable which is to be determined, an electrical output signal is generated by means of the homogeneous semiconductor layer (2, 2f), and in that this output

signal is conducted via at least two electrical conducting contacts (5) which are disposed on, at and/or under the homogeneous semiconductor layer (2, 2f) or are integrated in this semiconductor layer (2, 2f).

51. Measurement method according to claim 50,

characterised in that

a semiconductor sensor element according to one of the claims 1 to 49 is used.

52. Measurement method according to claim 50 or 51,

characterised in that

the physical variable to be determined is the pressure, the temperature, a force, a deflection and/or an acceleration.

53. Semiconductor structuring method for structuring a substrate base layer (1) and a semiconductor layer sequence based on main Group III-nitride elements, which is disposed on this substrate base (1),

the semiconductor layer sequence being masked on its surface orientated away from the substrate base (1) on a basic area which corresponds to a mesa which is to be etched out and

the semiconductor layer sequence being etched away outwith this basic area down to the substrate base (1) and

characterised in that

a homogeneous semiconductor layer (2f) of the semiconductor layer sequence, which semiconductor layer is connected to the substrate base (1), at least partially does not abut directly on the substrate base (1) on the basic area orientated towards the substrate base (1) or has a spacing from the surface of the substrate base (1) orientated towards said semiconductor layer, is etched out, by providing the basic area, which corresponds to the etched-out mesa of the semiconductor layer sequence, with an etching masking such that the etching masking does not cover the substrate base (1) in the region which abuts directly on the spaced region to be produced and by etching away the substrate base (1) both in the region which abuts directly on the spaced region and in the spaced region below the etching masking and the homogeneous semiconductor layer (2f), or by under-etching the etching masking and the homogeneous semiconductor layer (2f) in the spaced region and in that

at least two electrical conducting contacts (5) or an electrical contact layer are disposed on, at or under the homogeneous semiconductor layer (2f) or are integrated in the latter.

54. Semiconductor structuring method according to the preceding claim,

characterised in that

a semiconductor sensor element according to one of the claims 1 to 49 is produced.

55. Semiconductor structuring method according to one of the claims 53 or 54,

characterised in that

a raised region or mesa region (9) is etched out from the semiconductor layer sequence.

56. Semiconductor structuring method according to one of the claims 53 to 55,

characterised in that

etching in the spaced region and in the region abutting directly thereon is effected in the direction of the substrate base layer (1) to the semiconductor layer sequence.

57. Semiconductor structuring method according to one of the claims 53 to 55,

characterised in that

etching in the spaced region and in the region abutting directly thereon is effected in the direction of the semiconductor layer sequence to the substrate base layer (1).

58. Semiconductor structuring method according to one of the claims 53 to 57,

characterised in that

the substrate base (1) contains silicon Si or is formed therefrom.

59. Semiconductor structuring method according to the preceding claim,

characterised in that

the surface of the Si substrate base layer (1) at the boundary to the semiconductor layer sequence is a [111]-surface.

60. Semiconductor structuring method according to one of the claims 53 to 59,

characterised in that

the semiconductor layer sequence has at least one semiconductor layer which contains semiconductor structures based on a main Group III-nitride in the form of $Al_xGa_{1-x}N$ or $In_xGa_{1-x}N$ or $In_xAl_{1-x}N$ with a relative element content of $0 <= x <= 1.0$ or is formed therefrom.

61. Semiconductor structuring method according to one of the claims 53 to 60,

characterised in that

the semiconductor layer sequence comprises a homogeneous semiconductor layer (2f) which contains GaN or is formed therefrom.

62. Semiconductor structuring method according to one of the claims 53 to 61,

characterised in that

the semiconductor layer sequence comprises a homogeneous semiconductor layer (2f), which contains GaN or is formed therefrom, and a cover layer (2e) made of AlGaN, which is disposed on this layer on the side orientated away from the substrate base, in

particular made of $Al_yGa_{1-y}N$ with $0.1 <= y <= 0.3$, particularly preferred with $0.15 <= y <= 0.25$.

63. Semiconductor structuring method according to the preceding claim and according to claim 55,

characterised in that

the semiconductor layer sequence is etched such that the cover layer (2e) remains in the raised region or mesa region (9), but not outwith thereof.

64. Semiconductor structuring method according to one of the claims 53 to 63,

characterised in that

the spatial region present due to the spacing between the substrate base (1) and the homogeneous semiconductor layer (2f) is filled at least partially with a non-metallic and non-semiconducting material.

65. Semiconductor structuring method according to one of the claims 53 to 64,

characterised in that

at least one layer of the semiconductor layer sequence is p-doped or n-doped.

66. Semiconductor structuring method according to one of the claims 53 to 65,

characterised in that

the etching masking is effected with a mask (7) which contains aluminium or is formed therefrom.

67. Semiconductor structuring method according to one of the claims 53 to 66,

characterised in that,

in the spaced region and in the region abutting directly thereon, etching takes place with a chemically assisted dry etching method, in particular with a reactive ion etching method with the assistance of halogens in the reaction gas.

68. Semiconductor structuring method according to the preceding claim,

characterised in that

the halogens have chlorine and/or fluorine, in particular in the form of a CF_4 plasma.

69. Semiconductor structuring method according to one of the claims 67 or 68,

characterised in that

the dry etching method is implemented with addition of an additive gas, in particular oxygen.

70. Semiconductor structuring method according to one of the claims 53 to 69,

characterised in that

ohmic metallisations and/or Schottky metallisations are applied as electrical conducting contacts (5) or electrical contact layers.

71. Use of a semiconductor sensor element according to one of the claims 1 to 49 as pressure, temperature, acceleration and/or force sensor or in order to determine the dimension of a deflection or of a measurement method according to one of the claims 50 to 52 in order to determine a pressure, a temperature, a force, a deflection and/or an acceleration.

72. Use according to the preceding claim in the field of micromechanics or in the field of high-temperature applications or in the automotive field.